NASA TT F-10,617

SOME CHARACTERISTICS OF METABOLISM AND CONDITIONED REFLEX ACTIVITY OF ANIMALS DURING PROLONGED STAY IN A HELIUM-OXYGEN MEDIUM

G. V. Troshikhin

Translation of "O nekotorykh osobennostyakh gazoobmena i uslovnoreflektornoy deyatel'nosti zhivotnykh pri dlitel'nom prebyvanii v gelio-kislorodnoy srede".
Doklady Akademii Nauk SSSR, Vol. 169,
No. 6, pp. 1480-1482, 1966.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON DECEMBER 1966

SOME CHARACTERISTICS OF METABOLISM AND CONDITIONED REFLEX ACTIVITY OF ANIMALS DURING PROLONGED STAY IN A HELIUM-OXYGEN MEDIUM

G. V. Troshikhin

Experiments were conducted with SS57, sexually-mature mice in air-tight chambers with controlled temperature and controlled helium-oxygen content (21 and 79%, resp.). When the temperature was 21-23°, the metabolism of the mice in the helium-oxygen atmosphere increased by 50% above the initial level during the first three days. The O_2-consumption decreased later but was always 10-15% above the controls (air atmosphere). Body temperature was decreased by 0.5-1.0° in the experimental animals. Both O_2-consumption and body temperature normalized when the animals were changed to the plain air atmosphere. Conditioned reflexes set in much more slowly in the experimental animals (as tested by the formation of a defensive conditioned reflex to white light). The mechanisms postulated are based on the heat conductivity of helium being 6 times that of nitrogen.

Study of the changes of the physiological reactions of man and animals /1480* during a stay in a helium-oxygen medium, in addition to being of practical importance for space medicine and divers, is of considerable theoretical interest in connection with the biological significance of the nitrogen of the air [4].

A number of authors have demonstrated the possibility of a prolonged life of man and animals when inhaling helium-oxygen mixtures [2, 6]. However, in these investigations no study has been made of the influence of helium on metabolic processes and the functions of the central nervous system. The purpose of this study is to fill this gap to some extent.

Method. The work was carried out using 80 sexually mature mice of the SS57 strain. The experiments were carried out in two air-tight chambers supplied with a closed air-regeneration system. The oxygen, as it was used by the animals, was fed automatically through a gas counter. One of the chambers was filled with a helium-oxygen mixture (21% oxygen and 79% helium); the other, in which the control group of animals was placed, was filled with air. The temperature in the chamber with the helium-oxygen mixture could be increased using a thermostat. An equal number of mice was placed in each chamber. Control de-/1481 terminations of the gas composition in the chambers were made twice each day using a Holden apparatus (for oxygen and carbon dioxide) and a GEUK-21 apparatus which we modified (for an admixture of nitrogen to helium). The oxygen content in the experiments fluctuated in the range 18-22%, the carbon dioxide fluctuated 0.1-0.7% and the admixture of nitrogen to the helium-oxygen mixture

*/Numbers in the margin indicate pagination of the original foreign text.

TABLE 1. DYNAMICS OF THE BODY TEMPERATURE OF MICE (M±) DURING THE EXPERIMENT

Серия (a)	Группа животных (b)	Исходная температура, °С (c)	(d) День опыта в гелио-кисло родной смеси											
			1	2	3	5	6	7	8	9	10	12	13	14
A	Опытная (h)	37,3±0,06	36,5±0,09	37,3±0,11	36,8±0,15	37,1±0,16	36,8±0,09	36,9±0,11	36,8±0,06	37,0±0,11	36,8±0,07	36,4±0,14	36,4±0,15	36,9±0,10
	Контрольная (f)	37,5±0,16	37,5±0,15	37,7±0,19	37,4±0,10	37,7±0,17	37,4±0,18	37,4±0,07	37,4±0,17	37,7±0,11	37,9±0,32	37,7±0,13	37,9±0,11	37,4±0,12
	P	Н. д. * (e)	0,001	0,05	0,005	0,025	0,05	0,001	0,005	0,001	0,005	0,001	0,001	0,005

(g) День опыта в воздухе			
1	2	3	5
37,4±0,14 37,2±0,09	37,1±0,10 37,6±0,15	37,2±0,12 37,2±0,09	37,2±0,11 37,2±0,15
Н. д. (e)	0,025	Н. д. (e)	Н. д. (e)

Серия (a)	Группа животных (b)	Исходная температура, °С (c)	(d) День опыта в гелио-кисло родной смеси										
			1	4	7	10	14	17	21	24	28	31	35
B	Опытная (h)	37,7±0,08	37,5±0,16	36,9±0,12	37,1±0,11	37,1±0,09	36,9±0,15	37,0±0,12	36,9±0,12	36,6±0,12	37,2±0,11	36,7±0,07	36,4±0,07
	Контрольная (f)	37,8±0,06	37,6±0,09	37,5±0,14	37,6±0,16	37,1±0,12	37,2±0,12	36,7±0,12	37,1±0,16	37,0±0,19	37,1±0,15	37,0±0,14	37,1±0,14
	P	Н. д. (e)	Н. д. (e)	0,005	0,01	Н. д. (e)	Н. д. (e)	Н. д. (e)	0,001	Н. д. (e)	Н. д. (e)	0,05	0,001

(g) День опыта в воздухе			
1	3	5	7
37,5±0,12 37,2±0,09	37,2±0,13 37,1±0,03	36,9±0,18 37,3±0,15	36,8±0,20 36,9±0,08
Н. д. (e)	Н. д. (e)	Н. д. (e)	Н. д. (e)

Legend: a = Series; b = Group of Animals; c = Initial Temperature; d = Day of Experiment in Helium-Oxygen Mixture; e = Unreliable; f = Control Group; g = Day of Experiment in Air ; h = experimental group.

was 2.5-5.0%. The total consumption of oxygen in 17 hours (in the period from 1600 to 0900 hours) was determined daily for the animals on the basis of the gas counter readings. An electrothermometer was used for measuring the rectal temperature of 10 mice in each group within the chamber without changing the gas composition. In addition, during the entire experiment the dynamics of formation of defensive conditioned reflexes of mice to white light (in 10 combinations daily) were studied within the chamber using a modified Aleksandrov-Tsibina apparatus [1].

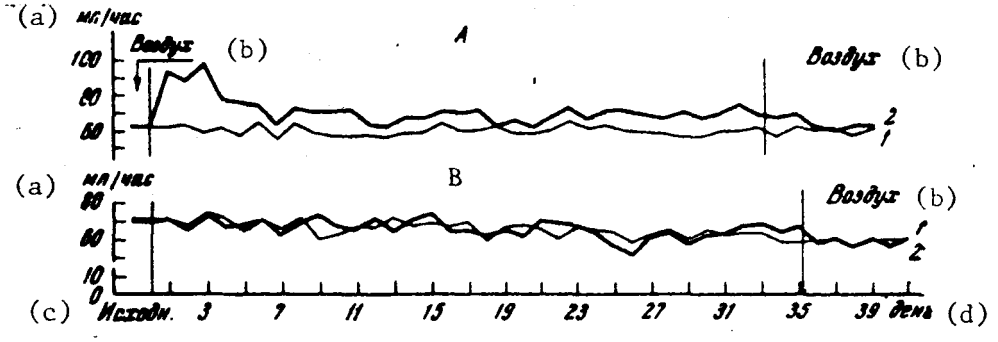

Figure 1. Dynamics of Oxygen Consumption by Mice During Their Stay in a Helium-Oxygen Medium. A = at Identical Temperature of "Air" and "Helium" Media; B = with Increased Temperature of "Helium" Medium. 1 = Control; 2 = Experiment. Legend: a = ml/Hour; b = Air; c = Initial; d = Day.

Results. These experiments revealed that in the mice in the helium-oxygen atmosphere when the air temperature was 21-23° the metabolism increases appreciably during the first three days (by 50% above the initial level). Later the oxygen consumption decreases, but during the course of the entire exposure is above the level of metabolism of the control group by 10-15%. After replacement of the helium-oxygen medium by an air medium during the first two days the oxygen consumption is maintained at a high level and then is normalized (Figure 1A). The body temperature in the experimental animals in comparison with the control animals was decreased by 0.5-1.0° during the entire exposure in the helium-oxygen medium. After a changeover to the breathing of air there was a leveling out of the body temperature to its initial level (Table 1, series A). /1482

During their stay in the helium-oxygen medium, the experimental animals revealed a lag in the development of the conditioned reflexes. The setting in of the conditioned reflexes in the helium group occurred on the average on the 19th day of the experiment (19 ± 2.5), and in the control group -- on the 8th day (8 ± 3.1). The difference between the groups is statistically reliable ($P = 0.01$).

Thus, in these experiments it was found that there was an appreciable influence of helium on metabolic processes and the conditioned reflex activity of mice.

There are few data in the literature on the possible mechanisms of the influence of helium on the body. Information is given on an intensification of the toxic effect of oxygen in the presence of helium in [5]. Some authors feel that helium can exert a possible direct stimulation of the metabolic processes at the cell level [9]. Another point of view also exists: that in biological respects helium is more neutral than nitrogen. Taking into account the high heat conductivity of helium, which is 6 times greater than the heat conductivity of nitrogen [6, 8], it can be postulated that intensification of metabolic processes in animals in a helium-oxygen medium at an ordinary temperature was accounted for by their cooling. Many investigators have noted a shift of the comfort zone for man and animals by 2-4° in the direction of an increase in a helium-oxygen atmosphere [2, 3, 6].

With these factors taken into account, in another series of experiments we increased the temperature of the medium filled with the helium-oxygen mixture by 3-4° in comparison with the "air" medium (21-23 and 24-26°). It was found that in this variant of the experiments, the oxygen consumption in the experimental and control groups of mice was almost identical (Figure 1B), although the rectal temperature of the experimental animals was somewhat low in comparison with the control group (Table 1, series B). There also was no difference in the conditioned reflex activity. In the mice of both groups the conditioned reflexes were formed at almost the same time (experimental group 9 ± 0.8; control group 8 ± 1.3; difference unreliable).

The results give basis for assuming that an increase of the level of oxygen consumption, decrease of body temperature and increase of the time of formation of the conditioned reflexes in mice in a helium-oxygen medium for the most part caused a considerable heat loss and a cooling of the animals as a result of the great difference in the heat conductivity of helium and nitrogen. The retention of an increased metabolism in mice for two days after replacement of the helium-oxygen medium by an air medium apparently can be attributed to some inertia of the processes of functional change of metabolism caused by the prolonged cooling effect of helium.

Institute of Physiology imeni I. P. Pavlov,
Academy of Sciences USSR

Article submitted
17 January 1966

REFERENCES

1. Aleksandrov, I. S. and M. G. Tsibina: Tr. Leningr. Inst. Gigiyeny Truda i Prof. Zabolevaniy, Vol. 2, Part 1, Sborn. Rabot Toksikologich. Labor., No. 4, Leningrad, 1947, p. 48.
2. Boriskin, V. V., P. A. Gul'tyayev and B. M. Savin: Sbornik Aviats. i Kosmich. Medits. (Collection of Papers on Aviation and Space Medicine.) Moscow, 1963, p. 78.
3. Breslav, I. S., A. G. Zhironkin et al.: Tezisy Nauchn. Soobshch. X S"yezda Vsesoyuzn. Fiziol. Obshchestva. (Summaries of Scientific Communications of the Tenth Congress of the All-Union Physiological Society.) 2(1): 121, Yerevan, 1964.

4. Vol'skiy, M. I.: DAN 128(4): 857, 1959.
5. Gul'tyayev, P. A., V. V. Boriskin, et al.: Tezisy Nauchn. Soobshch. X S"yezda Vsesoyuzn. Fiziol. Obshchestva. (Summaries of Scientific Communications of the Tenth Congress of the All-Union Physiological Society.) 2(1): 235, Yerevan, 1964.
6. Dianov, A. G. and A. G. Kuznetsov: Sborn. Aviats. i Kosmich. Medits. (Collection of Papers on Aviation and Space Medicine.) Moscow, 1963, p. 162.
7. Zal'tsman, G. L.: Fiziologicheskiye osnovy prebyvaniya cheloveka v usloviyakh povyshennogo davleniya gazovoy sredy. (Physiological Principles of the Stay of Man in a High-Pressure Gas Medium.) 1961.
8. Savin, B. M.: Sborn. Probl. Kosmich. Biologii. (Collection of Papers. Problems of Space Biology.) Moscow, 1963, p. 162.
9. South, F. and S. Cook: J. Gen. Physiol. 37: 335, 1954.

FRANK C. FARNHAM COMPANY
133 South 36th Street
Philadelphia, Pennsylvania 19104